E/CONF.39/A/198
29 Oct.1962
ORIGINAL : ENGLISH

UNITED NATIONS CONFERENCE
ON THE APPLICATION OF SCIENCE AND TECHNOLOGY
FOR THE BENEFIT OF THE LESS DEVELOPED AREAS

Agenda Item: A.5.2.2

Australia

SMALL-SCALE MINING EQUIPMENT

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SMALL-SCALE MINING EQUIPMENT

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1. Opinions differ as to what constitutes small-scale mining. An observer's judgement depends on the scale of mining to which he is accustomed, but for this paper it is assumed that the upper limit for small scale mining is the winning of up to 100 tons of material daily. This may be final product, or ore for further treatment. Within these limits may be found small company operations, privately owned mines employing a few men, and mines worked by self-employed men.

2. Small mines make a contribution to Australian employment which is considerably larger than their corresponding share of production. The low productivity per workman is compensated for financially by low overhead costs. Unfortunately this often means little or no technical supervision, or that if technical supervisors are employed they are often unqualified. For mines which are too small to employ technically trained men, the State Inspectors of Mines or officers of the Geological Survey give as much technical assistance as possible. If technically trained men are employed they must be versatile, not narrowly specialized.

3. In general, small mines have the following characteristics; (a) small and high-grade ore-bodies, (b) simple or no treatment plants, (c) simple mining methods which do not necessitate filling, (d) a minimum of waste or low-grade ore which if broken is left as much as possible in the stopes.

4. For small company operations, or even for privately owned mines, equipment is similar to or even identical with equipment used in large mines, except that in size it is often the smallest available. Some novel equipment is used in owner - operated mines and is discussed later in this paper.

5. Although a small amount of ore is won by hand tools, it is usual to use explosives. In soft material the holes for placing explosives may be bored by hand but this is now unusual and machine boring is almost universal.

6. Electrically driven auger drills are uncommon except in coal mines but have been used with success in a small chrysolite mine where the country rock was serpentine. In this case the electric auger-drill was mounted on a rock-drill cradle and advanced by a hand crank.

7. In most small metal or industrial mineral mines, holes for blasting are bored by compressed-air rock-drills. Compressed air is usually furnished by small portable or stationary compressors with a

capacity of 100 to 250 cu ft of free air per minute and driven by diesel engines of 25 to 50 h.p. It is common for these units to run unattended for most of the time while compressed air is required for rock-drilling or for ventilation. If a full-time hoist driver or treatment plant attendant is employed, a part of his duties is to service the compressor and engine.

8. Movement of ore or waste rock underground may be in small box-type cars holding ¼ to ½ ton but these can be used only in conjunction with properly timbered shafts and hoisting cages, unless the ore body is worked from adits only. It is more usual to transport ore in ¼ ton barrel-shaped containers with a handle. These are placed on top of a flat-topped four-wheeled conveyance running on rails, filled at the working place and hoisted through an open shaft by hooking the hoisting rope onto the handle of the container.

9. Hoisting of material is by single-drum winches powered usually by diesel engines. Compressed air is rarely used as the motive power. A common type of winch is one in which the source of power runs continuously, so that when not in actual use the clutch is out and the brake full on. In use the clutch is engaged and the brake released by hand levers and any failure on the part of the driver or the machine results in the immediate automatic application of the brakes. This is known as a "safety" winch, and in general, this type of winch is the only one on which the transport of men is permitted.

10. Winches may be operated by extension handles (usually made of 1 inch pipe) and by this means one man only is required for operating the winch and landing and emptying the containers of ore. These are usually emptied on to the ground from the shaft-head platform which is sufficiently high to afford room for a large stock-pile of ore.

11. For alluvial mining the most common small scale mining method is hydraulicking in which a jet of water is used for breaking up the material and transporting it to a sump from which it is pumped to a sluice box. It is unusual to have a sufficient head of water to operate the nozzle without pumps so that a typical small alluvial mine worked by this method would have the following arrangement: (a) water supply by ditch or pump from a nearby stream, (b) nozzle pump to provide pressure water for the hydraulicking nozzle, (c) sump pump for removing water and broken material from the mine, (d) elevator pump to lift the water and broken material to the sluice box.

12. The pumps are commonly 6-in or 8-in centrifugal pumps worked by independent engines, usually diesel, although some portable steam engines are still in use which use wood as a fuel. Sluice boxes may be up to 12 ft wide by 100 ft long.

13. The ores are treated by various methods. For base-metal ores, ball mills up to 5 ft in diameter, followed by a small bank of flotation cells or shaking tables are used. For gold ores the stamp battery is still common. Stamps are almost invariably in sets of five, each set being independently driven by a belt. Gold is recovered by amalgamation on plates followed by treatment on shaking tables where amalgamation is difficult, and cyanidation by leaching in vats. By by-passing the amalgamated plates the stamp battery may be used for recovering gravity concentrates from tin or

tungsten ores.

14. A substantial contribution to ensuring production from small mines, particularly those worked by self-employed men, is made by the State Battery Service of several of the Australian States. The largest of these services, which operate custom mills for the small miner, is that of Western Australia where the State runs 22 stamp batteries in different localities. Most of these are five-stamp batteries but there are six of ten stamps and one of fifteen. The larger batteries are run almost continuously with a permanent staff but the smaller batteries are grouped in districts and operated in turn by a travelling operating crew when sufficient ore accumulates to warrant a run of the battery. Total ore treated is about 40,000 tons annually.

15. The service was originally self-supporting but in recent years the scale of charges has not been increased proportionally with increased costs and the service is now run at a substantial loss.

16. Several examples of small-scale mining ore discussed below.

ECLIPSE MINES NO LIABILITY

17. The Eclipse mine, at Mount Magnet, in Western Australia, mines and treats 8,500 tons of high-grade gold ore annually. The total number of employees is 30, of whom three are technically trained and one is an accountant. The number of underground employees is eleven, comprising one supervisor, six miners, two hoist drivers and two loader operators and trammers. The number of treatment plant employees is four, including the metallurgist. The remainder of the employees work as surface labourers, engine drivers and workshop employees.

18. All ore production comes from two miners and the two loader-drivers and trammers. The remainder of the underground employees work on development and mine preparation. Ore breaking is from sub-levels into open stopes 4 to 12 ft wide, the broken ore falling to the tramming level below, where it is loaded by rail-mounted mechanical loaders into narrow-gauge waggons for hand-tramming to the shaft. Such mechanical loading is found to be more economical that the more usual loading from chutes directly into waggons because thereby little secondary blasting is required. Ore is won on four levels down to 866 ft below surface.

19. Ore treatment is by two stages of crushing followed by a 6 ft x 5 ft ball mill in closed circuit with two sets of cyclones (16 in and 3 in). The fine pulp is agitated with cyanide solution, filtered, washed and refiltered and the gold recovered from the cyanide solution by a conventional Merrill-Crowe system. Between the ball mill and the cyclones the pulp passes over a set of strake tables from which a concentrate is recovered. The strake concentrate is treated in an amalgam barrel and gold is retorted from the amalgam. The amalgam barrel residue is cyanided in a small agitator.

20. The mine, mill and workshop work only one shift daily for five days in the week, except that the cyaniding agitators are kept working continuously and outside the 40 ordinary working hours are supervised by the engine driver on shift in the power house, which is manned continuously. For this reason electrical consumption is very high - about 100 units per ton of ore mined and treated.

21. The mine has its own power plant, consisting of two 224 h.p. and

one 336 h.p. diesel alternators, one 180 h.p. air compressor and one 75 h.p. electrical compressor.

PARIS GOLD MINES PROPRIETARY LIMITED

22. The Paris mine, about 60 miles south of Kalgoorlie is a small gold and copper mine. Production started in 1961 and when the property is fully equipped it is expected to produce 5,000 tons of ore annually. In 1961, production was 1,350 ounces of gold and 80 tons of copper concentrates from 2,800 tons of ore.

23. The total number of employees in early 1962 was 42, of whom the manager is the only person with technical training. Six men were employed in the treatment plant, 21 underground and the remainder in construction and other services. The mine works two shifts of 7½ hours daily on five days per week, the treatment plant, continuously in three shifts of 8 hours.

24. Underground equipment and methods are entirely conventional consisting of hole-boring by compressed-air drills, breaking by explosives into shrink stopes, hand-tramming to the shaft and hoisting by A.C. electric winder. The deepest working level is at 300 ft below surface.

25. Treatment of ore consists of going through two stages of crushing, a small ball mill and flotation cells. Between the ball mill and flotation cells the pulp passes over a set of strakes from which a gold concentrate is obtained. Gold is recovered from this concentrate by an amalgam barrel and retorts and produces quick revenue. The copper concentrate is exported to Sweden.

26. The mine power plant consists of two 500 h.p. diesel alternators.

DAISY MINE, MOUNT MONGER, WESTERN AUSTRALIA

27. The Daisy Mine is an example of a mine operated by a working proprietor with a few employees, in this instance five.

28. The mine has been worked out to 374 ft below surface from two shafts. All work at present is between the 374 and 487 ft levels. The average width of the ore body is 2½ ft and the length 90 to 150 ft but the high-grade payable portions occur only in shoots about 15 ft long.

29. Ore is broken by explosives using compressed air operated percussion drills trammed to the operating shaft in containers on flat-topped trolleys and hoisted by a safety winch as described in paragraphs 8 and 9.

30. The property is equipped with a treatment plant and formerly treated its own ore but it is cheaper now to send all ore by road for treatment at the State stamp battery at Kalgoorlie, a distance of 45 miles. Production is about 800 tons of ore annually having a gold content of about 1 ounce per ton.

SMALL-SCALE LEACHING OF COPPER ORE IN PLACE

31. A large number of small copper mines were worked in Australia between 1850 and 1900. In some of these, a considerable tonnage of low- grade oxidized ore was left in place as stope filling. Leaching

of this material and recovery of the copper has been successfully achieved in several of these old mines - details are given below of two of these operations.

32. This method could be applied to ore deliberately broken for the purpose. Holes drilled into stope walls or parallel with the walls of old open cuts for sampling could be used for blastholes if the oxide copper content is thereby shown to be sufficient.

33. Sulphide ore alone is not suitable for leaching, although some sulphide material is desirable as a source of sulphate ion which is necessary to dissolve the oxide and carbonate copper minerals. If there is no other source of sulphate ion, sulphuric acid may be added to the leaching solutions. Two examples of leaching in place are given below.

BUDGERY MINE, HERMIDALE, NEW SOUTH WALES

34. In 1947 leaching operations began on the Budgery mine. Apart from several periods of a few months when the mine was closed for lack of water or to allow the ore to partly dry and oxidize, the mine has operated continuously producing about one ton of precipitates weekly with a copper content of 70%.

35. A stainless steel plunger-type pump was installed at the 240 ft level and worked by a 4 h.p. diesel engine on the surface through a pump jack with a 9 in stroke and ¾ in steel rods. The pump required very little attention or maintenance and worked for seven years before replacement.

36. The pumped solution, about 700 to 800 gal/hr passed through a set of 4 rectangular reinforced concrete cells each 10 ft long, 3 ft wide and 3 ft deep. The cells were fitted with a wooden grating with ½-in openings, half-way up the wall of each cell. The cells were connected by 4-in stainless-steel tubes let into the concrete. After passing through each cell in turn the solution was returned underground for further leaching. Tin plate scrap was used as the precipitating agent.

37. The scrap in the cells was agitated every 20 or 30 minutes by shaking it up with a wooden pole or a piece of stainless-steel pipe.

38. Each precipitation cell had an 18 in x 9 in opening at the lower end over which a rubber lined door was fastened by two stainless-steel bolts let into the cell walls. At intervals the cells were drained and the copper precipitate drawn off into a concrete draining yard where about 80% of the moisture was drained off. When drained, the precipitate was further dried on a steel plate heated by a wood fire to a moisture content of 2½ to 5% and bagged for despatch to a smelter. The steel drying plate overlapped slightly the walls of both the draining yard and bagging yard in order to minimize loss in handling.

39. The inside area of concrete precipitation cells, sumps and draining yard was lined with a mixture of 40 parts of Portland cement and 60 parts of coal tar applied hot in several layers to a thickness of about ¼ inch.

40. The tail solution was distributed over the ore in the stopes by "sprinkler hose", which is plastic hose with 3/16-in holes punched

or burnt in it at 8 ft intervals and joined by pieces of stainless steel piping. Any holes in the hoses not required were closed with wooden plugs. By changing the positions of the sprinkler hoses an even distribution of the solution over the ore was obtained.

41. Solution was delivered from the underground pump to the precipitation cells through rubber hose (6 ply, 5 ply and 4 ply from the bottom up). This hose lasted 4 to 5 years, rubbing on shaft timber being the chief cause of wear. The return distributing hose lasted for 6 to 7 years. Water used was natural mine water supplemented by rain water when available. No addition of sulphuric acid was required.

MOUNT HOPE MINE, MOUNT HOPE, NEW SOUTH WALES

42. In 1948, leaching was begun at the Mount Hope mine, where similar equipment to that used at the Budgery mine was used, the only difference being that the pump worked on a 12 in stroke and delivered 1000 gal/hr.

43. The water in the mine contained very little copper, iron or acid at first but after recirculation by spraying over the broken ore in the old stopes for a period of three months the copper content rose to 8 grams per litre. The mine was estimated to contain 50,000 tons of broken ore in old stopes with a 4 % oxide copper content.

44. After three months recirculation of water, precipitation was begun, using equipment similar to that used at the Budgery mine. After twelve months precipitation, production of copper fell sharply and the acid content of the solution was found to be too low. This was corrected by adding sulphuric acid to the tail solution at the rate of 5 grams per litre until the copper content of the head solution reached 7 grams per litre. Addition of acid was then reduced to 3½ grams per litre, which maintained the copper content of the solution at 5 grams per litre.

45. Sulphuric acid was obtained from Sydney in 44-gallon steel drums at a cost of £A21 per ton, plus freight. In 1956, copper content of mine solution had fallen to 3 grams per litre and total iron content had risen to 4½ grams per litre. At this point the tail solution was pumped to waste for a period of six months and replaced in the mine by fresh water. Circulation of solution over the ore and addition of acid was then begun and continued for three months, when precipitation was begun again with a copper content of 5 grams per litre in the head solution.

46. Agitation by compressed air of the scrap in the precipitation cells was tried and was successful but was more expensive than hand agitation as at the Budgery mine.

47. The thanks of the Bureau of Mineral Resources are expressed to the managers or proprietors of the mines described in this paper and to Mr. A.G. Reid, Inspector of Mines at Orange (Department of Mines, New South Wales) from whose paper entitled "Small-Scale Leaching and Precipitation of Copper from Mines in New South Wales" the information in the last section of this paper was extracted.

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